A systemic methodology to characterize peri-urban agriculture for a better integration of agricultural stakes in urban planning

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Urban fringe

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RÉSUMÉ.— Les documents d'urbanisme existants tiennent difficilement compte des spécificités de l'agriculture périurbaine en tant qu'activité économique nécessitant des aménagements non obligatoirement adaptés à la vision urbaine des espaces agricoles. Nous proposons une méthodologie de caractérisation des unités spatiales d'agriculture périurbaine (USAPU) permettant de réaliser un état des lieux des espaces agricoles périurbains adapté aux contraintes des praticiens de l'urbanisme. Notre démarche se veut un outil permettant de focaliser l'action publique sur les zones où elle a le plus de probabilités d'être efficiente dans un projet de territoire.

Action publique, Agriculture périurbain, Avignon, Méthodologie, Planification urbaine

Abstract— Community concerns about peri-urban agriculture legitimate its protection in planning. However, existing planning tools hardly take into account the specificities of agriculture as an economic activity requiring facilities that are not necessarily related to urban vision of farming spaces. Looking for supporting the integration of peri-urban agriculture in urban planning, we propose a methodological framework to characterize homogenous spatial units of peri-urban agriculture (USAPU) enabling to make an assessment adapted to planners' constraints. Our approach seeks to be a tool to steer public action toward areas where it will be most efficient for developing a territorial project.

Methodology, Periurban agriculture, Avignon, Public action, Urban planning

Introduction

Urban sprawl (with a 78 % increase in surface area since the 1950s) as well as peri-urban development represent the two major challenges in Europe (European Environment Agency, 2006). In France, peri-urbanization and urbanisation of agricultural land are also crucial stakes and the outer boundary of the peri-urban area is shifting increasingly away from the city centre (Baccaïni, Sémécurbe, 2009). Today, the emerging social demand and concerns about

environmental issues (water quality), living conditions (health) and food security legitimize taking agriculture into consideration in city-related territorial projects. In addition, agricultural landscapes and functional eco-systems of the cities are interlinked with respect to their role as ecosystem service providers - like the catchment area providing drinking water (Nassauer, 2012) - or by way of agricultural multi-functionality providing ecological, economic and territorial benefits (Guillaumin *et al*., 2008).

While agriculture has already been characterized by its role as a lever for rural development (Lardon, 2012) or in terms of ecosystem services that it generates (Termorshuizen, Opdam, 2009), there has been little research on the interactions between peri-urban agriculture and urbanized areas. Ambiguities in the definition of "peri-urban" also make it difficult to demarcate and characterise peri-urban agricultural areas, especially from the perspective of public action (Chery, 2011). The most frequently used criteria are based on the notions of proximity (being located close to the city) and functionality in terms of links maintained with the city (Nahmias, Le Caro, 2012). It is thus pertinent to distinguish peri-urban agriculture, juxtaposed with the city, from urban agriculture, which would deal with functional relations within the city (Fleury, Donadieu, 1997). However, empirically, farmers in a peri-urban situation can be seen to interact with the city and take its specificities and needs into account. But many are only marginally affected and, in any case, less affected by their close geographic context than by the trends related to the dominant agro-food industries in the region (for example, cereal farmers in urban districts produce wheat for national cooperatives)(Soulard *et al*., 2016). In an effort to elaborate the definition of peri-urban agriculture, we explored the criteria related to the notion of proximity. We will analyse all forms of agriculture found in the vicinity of a medium-sized city (Avignon) with respect to their morphological and productive dimensions, whether they are in a functional relationship with the city or on the contrary, following the logic of agro-industrial sector. Indeed, by looking at it from the perspective of urban and spatial planning, we assume that distance alone is not sufficient to define agricultural areas that are functionally related to the city. Furthermore, the diversity of agriculture surrounding the cities has to be characterized in order to steer public action to the most appropriate areas.

Specifically, productive and market-based peri-urban agriculture has often been integrated into urban planning projects for its landscape and aesthetic dimension as a part of the system of open spaces in the city or as a space meant for future development, thus without being considered as a productive economic activity (Valette, 2014). Over the last few years, however, proposals from architects, landscape architects and urban planners have been contributing to a reflection around the integration of agriculture into the city, which has become "fertile"[1] in contrast with the figure of the "sterile city" that illustrated the opposition between city and agriculture in the 20th century (Cavin, 2012). For example, the notion of contiguous productive urban landscape by Viljoen and Bohn (2014) or the trend of edible landscape (Bhatt, Farah, 2010), which develops architectural systems for the purpose of integrating fruit and vegetable crops into urban areas.

However, these proposals do not properly address the issues inherent to peri-urban agriculture. Urban sprawl and increased overlapping between cultivated and urbanised areas inevitably have an impact on the activities, practices and organization of agricultural labour. For example, loss of productive intensity that can be observed in various forms of peri-urban agriculture is determined by the difficulty in finding agricultural labour in the outskirts of a city (Olmo, Chumillas, 1987), development generated by the city (infrastructure) or various types of noise and air pollution (Melot, Torre, 2013). Land price dynamics is also related to proximity to big cities and has an impact on the strategies or the sustainability of peri-urban farms (Jouve, Napoléone, 2003).

Finally, most of the proposals made by architects, urban planners and landscape architects cover limited city space and are developed in urbanised areas while it is possible to cover larger areas through agriculture in peri-urban areas. "At the current stage of knowledge and tools, what we need to consider is a shift in the territorial scale" (Peltier, 2010). Despite the explosion of research on urban and peri-urban agriculture (Daniel, 2013), the theoretical and methodological concepts need to be improved further in order to include agricultural areas in the urban system for urban planning purposes (Vidal, Fleury, 2009).

In this respect, this paper proposes a systemic methodology for characterisation of agricultural

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1 For example, the theme of "fertile city" was the topic of an exhibition at the Cité de l'architecture at Paris in 2011, http://www.citechaillot.fr/data/expositions_bc521/fiche/22796/dp_villefertile_defdef_90731.pdf.

areas and activities on the outskirts of a city. This methodology is designed to be an operational tool for urban planning that would allow us to consider agriculture as a land useas much as a productive activity. Our theoretical framework is addressed to urban practitioners as well as decision-makers. Our objective is to develop a generalizable methodology that refers to pertinent elements for public action with a focus on areas where it is more likely to be effective and where it would even be able to steer agriculture towards a preferable dynamics for the common good: landscape protection, protection of local production by selecting the desired agricultural system close to cities (an ecological form such as certified organic agriculture, for example) or, alternatively, facilitate the disappearance of agriculture to leave room for socially more important usages.

Issues pertaining to agriculture in peri-urban areas: components and driving forces

In order to conceive a methodology for integration of peri-urban agriculture into landscape planning, we looked for tools and mechanisms that could be developed to take the agricultural issues into account. Landscapes, in the sense of land use patterns, can be a working tool allowing us to elaborate land use scenarios and consequently, a tool that can be used for spatial and strategic planning (Nassauer, 2012). In addition, at the local and regional level, landscape takes on a subjective dimension, perceived by the inhabitants as characterising a part of the territory[2] and as a vector of cultural identity (Helming, Pérez-Soba, 2011). Henceforth, landscape becomes a shared material, which can be manipulated collectively in a project-based approach (Antrop, Rogge, 2006).

In more concrete terms, we undertook to create a concept map of the external and internal forces controlling the dynamics of farming systems in peri-urban areas. In fact, geography recognises multiple heterogeneous forms of peri-urban agriculture characterised notably by the uncertainty of agricultural land use (Guiomar, 2014). Using trends identified during our literature review and fieldwork, we mapped the external influences on the evolution of peri-urban agricultures and subsequently, the internal elements governing their organisation and dynamics.

Several external forces were identified: the Common Agricultural Policy (CAP) (Bartolini, Viaggi, 2013), efficiency of agro-food companies with a comparative advantage in terms of labour costs[3] (Eurostat, 2013), commodification and standardisation of production as well as precision and regularity in the supply as required by international trade rules, which are however generally applied to all producers (Durbiano, 1996), climate change and adaptation of production and livestock systems (Bryant *et al*., 2016), the regional structure of agricultural sectors (Soulard, Thareau, 2009), urban demands related to food security and sovereignty (Connell et al., 2013).

The internal forces determining peri-urban agricultural forms are of two main types. We first distinguished the forces that come under farming related factors: size, fragmentation and scattering of field plots, the type of land tenure, the degree of specialisation, etc. (Zasada *et al*., 2013).

Other factors in the surrounding areas also play a role. For example, the existence of sufficient density of farms to allow professional interactions (Poulot, 2011), the location of the farms buildings and the possibility of constructing new ones(Nougarèdes, 2011), the proximity to residential areas leading to restrictions on the number and the schedule of pesticides and fertilizers applications (Lefebvre *et al*., 2004), the peri-urban road network morphology and restrictions on movement of agricultural machines between the fields, the storage facilities and sheds (Morlon et al., 2006). Subsequently we distinguish the forces related to the agricultural family structure (farmer's age, succession ensured or not, type of labour employed on the farm – family or not (Smithers, Johnson, 2004). All these forces interact to shape the various agricultural land uses and types of peri-urban agriculture (Fig. 1).

Fig. 1/ Conceptual map of the internal and external forces shaping the forms of peri-urban agriculture

Our hypothesis is that these forces are reflected in the landscape through elements that may be described using a three-tier approach (Piorr, 2003): a) structure of the landscape or the morphology of peri-urban agricultural areas; b) functioning of the landscape, that is, the socio-economic dimension of agricultural activities and c) management and regulation of the landscape,

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2 European Landscape Convention signed at Florence in 2000 defines the term "landscape" as a part of territory as perceived by the population, whose nature is the result of the action of natural and/or human factors and their interaction.

3 For Avignon, it is products from south of Spain, Italy, Maghreb or South America.

that is, the policies influencing land use and preservation of agricultural land.

Materials and methods

We developed a systemic approach drawing on the work done by Jean-Pierre Deffontaines on characterisation of *Agro-Morphological Units* (*Unites Agro-Physionomiques* – UAP)(Deffontaines, Thinon, 2008; Lardon, 2012, Rizzo *et al*., 2013), by using remote sensing methods, field surveys and on-site analysis of the landscape. The approach based on Agro-Morphological units combines geography and agronomy for planning purposes where landscape is the key to a geo-functional analysis of the territory. It consists of defining homogeneous areas in terms of agricultural morphology and usage. The notion of Agro-Morphological units is thus based on the hypothesis that for each type of agriculture, there is a corresponding combination of forms that defines it in space and provides a visible image. In this framework, our objective was to build a methodology for characterising peri-urban agriculture that would enable us to develop a typology of peri-urban agricultural spaces at the landscape level in order to steer public action to specific zones. The non-random layout of cropping systems and types of urbanization in the territory leads to a pattern-based arrangement of forms produced by each cropping system and each type of urbanisation. The morphological analysis of the landscape's spatial patterns, coupled with a geo-functional interpretation based on the analysis of spatialised data using a GIS and field surveys, enabled us to demarcate and characterise homogeneous zones that we have named "spatial units of peri-urban agriculture" (*unités spatiales d'agriculture périurbaine* - USAPU). The USAPUs are homogeneous spatial entities in terms of planning as well as agricultural and urban uses that allow us to understand peri-urban agriculture. Bigger in size than a plot, a USAPU is a portion of land, which is not necessarily contiguous (it may be made up of several "spots"), made up of a main agriculture form associated with a particular type of construction (for example, a mosaic of vegetable gardens and isolated houses). The USAPUs make it possible to segment a wide territory into morphologically and functionally homogeneous spatial units (in our case study, between 20 and 40 square kilometres in size), which are pertinent and operational for landscape planning. The process of constructing the notion of USAPUs is based on the empirical analysis of a case study around the urban area of Avignon, in an inductive approach seeking to develop a generic methodology that can be applied easily to other case studies.

Study area

The urban area of Avignon[4] issituated in the region of Provence-Alpes-Côte d'Azur (PACA). Its development is based on the individual housing model, and thus it is scattered and sparse (AURAV, 2013). This type of urbanisation, which was existed since the 1970s, can be attributed to a sharp demographic growth combined with a highly developed road network and a flat terrain facilitating construction (Bisault, 2009). It is an "urban planning, which seems to have been developed without rules or projects, which offers identical and general forms all over the country, from the north to the south" (Agence Paysages et al., 2013). This territory is endowed with alluvial soils, a Mediterranean climate (mild and humid winters and hot and dry summers) and several rivers. It is thus very fertile and its agriculture is productive (Baccaïni, 2012). Since late 19th century, with the development of the railway network, Avignon's plains started producing fresh fruit and vegetables as well as wine, which were shipped to consumption zones such as Paris or London (Grosso *et al*., 1993). Even though activity is nowadays geared towards the service industry, the territory retains its strong agricultural specificity[5]: agriculture represents 11 % of the establishments[6] (INSEE, 2013) and the share of agricultural employment (4,9 %)[7] is today twice as high as in comparable territories[8] (Chauvot, Pougnard, 2012). However, uncontrolled urban

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4 This urban area was defined by INSEE in 2010. For the record, an urban area is, according to INSEE, a set of *communes*, which are contiguous and without enclaves and made up of an urban hub and its peri-urban ring where at least 40 % of the resident population has a job in the perimeter of the urban area.

5 Due to early ripening as compared to the other French regions, six types of vegetables (squash, zucchini, melon, turnip, tomatoes and salad leaves) and six types of fruit (apricots, cherries, peach-clingstone peach-nectarine, pears, apples and table grapes) make up for most of the cargo (Agreste, 2009).

6 An establishment is, according to INSEE, "a geographically individualized production unit, which is however eventually legally dependent on a company. An establishment produces goods or services: it may be a factory, a bakery, a garment shop, one of the hotels belonging to a chain of hotels, a "boutique" for repairing computer material, etc."

7 In the *communauté de communes* of Pays de Sorgues and Monts de Vaucluse, included in the urban area of Avignon and in the perimeter of our study area, the agricultural activity sector represents 22 % of jobs.

8 INSEE created a frame of reference made up of comparable entities to compare territories and identify the specificities or issues pertaining to each of these. Regarding the urban area of Avignon, this frame of reference corresponds to urban areas with a population of

development of the Avignon agglomeration has created a very high pressure on agricultural land, notably with a price competition effect. This pressure threatens the sustainability of agricultural areas, including those that are productive and profitable (Geniaux *et al*., 2011). In fact, the land meant for construction is sold at rates that are 55 times higher than those retained for agricultural use (Geniaux, Napoléone, 2005). Consequently, the agricultural area used (*surface agricole utilisée* – SAU) in the urban area of Avignon located in the PACA region has diminished by 22 % over the last thirty years (Chauvot, Pougnard, 2012).

Given the significance of real estate prices with respect to the future of agriculture use, we demarcated our study area on the basis of the relationship between ground rent and urban growth in order to estimate the city's area of influence on agriculture. More specifically, on the basis of a dynamic urban model in the lines of "Alonso, Muth and Mills", which formalises localisation of people and activities according to real estate rates and transport costs (Alonso, 1964), we demarcated the outer limit of the city as the point where urban real estate and agricultural rates meet (the point where the city has no effect anymore on the land prices)(Fig. 2). In explicit terms, the outer limit of the peri-urban area is situated, in view of the topic of our paper, at the distance beyond which it is not profitable anymore for the urban people to move further away from the city because of the increasing transport costs. Given that in the employment zone of Avignon, travel by car represents more than 90 % of the journeys and the average travel time from residence to work for an individual working outside his/ her residential municipality was 34 minutes in 2004 (De Plazaola, Melquiond, 2008), we retained the peri-urban boundary at a normal distribution quartile (45 minutes) away from the main employment hubs located near the first ring of peri-urban towns in the surrounding areas of Avignon (AURAV, 2011). Subsequently, as far as the inner limit of the peri-urban area is concerned, it is theoretically defined as the point where consent to pay of the farmers for the land becomes irrelevant, because of the anticipation effect of the change in land use (Sinclair, 1967; fig. 2). In concrete terms, we determined this limit according to the density of the urban areas using Corrine Land Cover classification (level 3), by retaining artificial continuums (codes starting with "1"). Thus, in the case study of Avignon, the peri-urban is located between the dense urban fabric and the countryside situated at a distance-time of 45 minutes driving from the employment hubs.

Fig. 2/ Theoretical model proposed to demarcate peri-urban agricultural areas

Finally, we superposed the boundaries induced by distance-time and density of the urban areas, with the provisions preserving agricultural land from urbanisation in enforceable urban planning documents: the Territorial Coherence Programme (*schéma de cohérence territoriale* - SCoT) (SCOT) and the Classified Forest Areas (*espaces boisés classés* - EBC). The study area thus defined corresponds to a part of the Sorgues basin, demarcated by the Rhone river on the west, Durance river and Avignon highway (D900) on the south, Vaucluse mountains on the east and Sorgue d'Entraigues stream on the north (Fig. 3).

Fig. 3/ Study area of Avignon

Approach

We applied a two-phased methodology to our study area: first, we carried out a diachronic analysis of land use based on remote-sensing techniques using Landsat satellite images, for three periods: the 1970s (urban expansion facilitated by the automobile boom); late 1980s (implantation of major commercial areas with the development of mass retail) and the current period (generalised and disorderly urban expansion). We geographically identified the specific areas where the main change in land use (urbanisation) is taking place, in order to localise areas where agriculture could be subject to a stronger land pressure. We then carried out a comprehensive geo-functional analysis in order to identify, in these spaces, homogeneous areas in terms of use, tenure and agricultural practices. This analysis was conducted in several iterative stages to identify the landscape patterns and homogeneous zones with the same pattern through visual morphological analysis of aerial images and ortho-photos as well as analysis of spatialised data with the help of a GIS. We defined geographic, agronomic, economic and political data required to design our concept map of inner and external forces shaping forms of peri-urban agriculture.

Data analysis was supplemented by a field survey in the urban area of Avignon in the spring of 2015. We interviewed fourteen farmers, three elected representatives of the *communes* (the Mayor

anywhere between 275000 and 700000 inhabitants in 2008, on one hand, and a demographic growth higher than 0.6 % par year in the period 1990-2008, on the other hand. In France, ten urban areas, all of them located to the south of a northwest-southeast axis, corresponds to these criteria: Grenoble, Rennes, Toulon, Montpellier, Tours, Orleans, Caen, Angers, Perpignan and Bayonne.

and his deputies) and three local experts (representatives of farmers and technicians working in the field, for example, at the Chamber of Agriculture or in a cooperative), in order to better understand the evolution of the farms and the factors determining farmers' strategies. These semi-directive interviews lasted approximately one hour each and were analysed using an interview grid (Box 1). All of them were anonymised. These landscape, geographic and interview-related elements allowed us to distinguish eight USAPUs in the Avignon zone.

Box 1/Interview grids

Farmer interviews

The questions pertained to the course of their working life and on the evolution of the farm to retrace their trajectory. The objective was to identify the determining factors for changes to understand the current strategy of the farmers. These interviews were analysed using the following grid: farmer – municipality – internet – age – place of birth – strategy – social background – training – farming since when – full time/ half time – motivation for becoming farmer – satisfied/not satisfied – successors – formal/informal associations – machines – farming – farm division – relationship with the townhall – relationship with the *département* – relationship with CAP (subsidis) – work-related obstacles (difficulties) – mode of irrigation – crops (ha) – previous crops (ha) – reasons for change of crops - organic/conventional – production intensity/rotations –production strategy –employees/family/seasonal AWA (annual working units) – marketing.

Interviews with local elected representatives

The questions pertained to the local public action in the municipality and the local impact of national and European policies (for example, CAP).

The objective was to understand the evolution of public action and how the organisations have adapted to the new policies. These interviews were analysed using the following grid: decision-maker – local public action – local impact of higher-level policies – evolution of public action – adaptation by the organisations.

Interviews with local experts

The questions pertained to the policies related to land development, agriculture and conservation of natural areas and biodiversity in order to retrace their evolution. The objective was to identify the key events, which played an important role in the evolution of peri-urban agriculture and which shaped the current situation, and then to compare their responses with the elements identified in the literature review. These interviews were analysed using the following grid: type of expert – territorial development policies – natural area policies – agricultural policies – evolution.

Results

Demarcation and qualitative characterisation of spatial units of peri-urban agriculture

Eight spatial units of peri-urban agriculture (USAPUs) were thus defined (Fig. 4):

• USAPU-A: *urbanisation front* alongside diversified agriculture on a small and unstructured plot around a dense road network. This unit is characterised by small and medium farms mainly geared towards greenhouse horticulture, diversifying into arboriculture and small-scale livestock farming, with a strong presence of housing clusters. The farms use several marketing techniques, from shipping to on-farm sales.

• USAPU-B: *"opportunistic" agriculture*, characterised by subsidized cereal crops of durum wheat on former vegetable gardens or tree-growing areas that were earlier compartmentalised by hedges running east to west, with a few fragments still standing.

• USAPU-C: *small farms that are diversified and fragmented* for reasons non responding to agricultural sector rationale. These farms have small crop plots located close to built-up areas. USAPU C is a mix of vineyards, grassy areas, wasteland (possibly due to grubbing-up of vines), small vegetable gardens and isolated constructions.

• USAPU-D: *long-standing horticultural belts* irrigated through a system of canals with vegetable gardens grown in open fields or greenhouses around the farmstead. This USAPU is characterised by medium-sized crop plots intertwined with a few long plots surrounded by hedges, which were still in arboriculture in the 1970s;

• USAPU-E: *long-standing fruit arboriculture* composed of orchards on very long crop plots (40 meters of width on an average for 200 metres of length), surrounded by hedges running west to east as protection from the wind.

• USAPU-F: *leisure and equestrian clubs*, located in small spots around villages or hamlets, intertwined with other USAPUs. This USAPU is characterised by a high density of riding schools, schooling yards and stables. In the vicinity, there are plots with meadows used as pastures or mowed down for hay, alongside other plots used for vegetable gardening, arboriculture or lying fallow.

• USAPU-G: *viticulture (AOC)*, characterised by vineyards on two types of crop plots: rather big crop plots (length and breadth of around 400 metres) with a discontinuous hedgerow structure, often around a farmhouse, and on the other hand, closer to the town, a smaller and irregular crop plots (plots of around 100 x 250 metres) with denser hedgerows , a few plots of abandoned vineyards and reverted lands.

• USAPU-H: *hill slopes* at the "low mountain areas" characterised by mixed farming and livestock farming in small plateaus or terraces.

Fig. 4/ Location of spatial units of peri-urban agriculture (USAPU) in the study area of Avignon.

The USAPU location map shows that they are not distributed in a distance gradient from the city centre in a "von Thünen"-like pattern[9]. For example, viticulture (USAPU-G), the agricultural activity requiring the least contact with the town, is the closest to the reference city centre (Avignon city).

Statistical characterisation of the spatial units of peri-urban agriculture

After the qualitative characterisation of the USAPUs, we compared them with available data in order to evaluate the statistical characteristics that could define them and the environmental elements that could explain their nature or location. For example, for the morphology of the territory, we retained variables characterising the road network (form, density, regularity), the crop plots (form, layout in the farm, whether it is a grouped or a scattered plot, slope and orientation) and the built-up fabric (density, fragmentation, relationship with cultivated fields, evolution of artificialized areas)[10]. We retained a total of 75 possible variables that we used for carrying out correlation analyses[11] as well as multidimensional factor analysis, i.e., multiple correspondence analysis (MCA), in order to reduce the number of variables from 75 to 10 significant variables (Box 2).

Box 2/Significant variables characterising spatial units of peri-urban agriculture

• "% of expanding farms*": percentage of afarms, within a single USAPU, that have increased their farming surface area.
• "% of shrinking farms": percentage of farms that have reduced their farming surface area.
• "% of professional farms": percentage of farms with a cultivated agricultural surface area higher than or equal to 1 hectare, or with specialised crop area higher than or equal to 2000 square meters (conditions pertaining to size for the general agricultural census (*recencement général agricole* – RGA) to statistically define a farms).
• "% of farms > SMI": percentage of farms with a surface area higher than the area established by the *Mutualité sociale agricole* of Vaucluse as the minimum installation area (*surface minimale d'installation* – SMI), according to the technico-economic orientation (*orientation technico-économique* – OTEX) of the farm.
• "% maj. mono. farms": percentage of mono-oriented farms according to the predominant OTEX found in the spatial unit of peri-urban agriculture.
• "% classified as agricultural under PLU": percentage of the total surface area of the spatial unit of peri-urban agriculture classified as agricultural under the local urban planning scheme (*plan local d'urbanisme* – PLU) of the concerned municipality.
• "% of artificialized area": proportion of land under the "artificialized" land use category assessed visually in the land use map obtained using remote-sensing analysis of satellite images from 2011. Five categories were defined: non-built-up (no buildings nested in agricultural areas of the spatial unit of peri-urban agriculture), lightly built-up (very few buildings nested), a little built-up (a few buildings nested), quite built-up (many nested buildings), quite built-up with spots of clustered buildings.
• "form of the border between USAPU's agricultural spaces and urbanised spaces": assessed using a visual analysis of the orthophotos at the scale of the spatial unit of peri-urban agriculture in 2011. Three categories were defined: juxtaposition (in the fringes of built-up areas), imbrication with built-up areas and absence or little contact.
• "form of the cultivated crop plots": visual morphological analysis using orthophotos at the scale of 1/5 000 in 2011. Three categories were defined: compact (plots with a clear geometric form, rectangular or square), fragmented (plots with twisted forms), irregular (combination of compact and fragmented plots without any predominance of one form over the other).
• "type of tenure": percentage of the number of land plots cultivated as an indirect tenure (no owner-operated).
* This variable and the four subsequent ones were calculated using declarations made to *Mutualité sociale agricole* (MSA) in 2006 (and in 2005 and 2004 as well for the first two variables).

The graphic representation of the MCA Burt table on the ten retained variables highlights the nature of each USAPU and charts elements explaining the observed variance (Fig. 5). On the horizontal axis, the variables with significant contributions are those related to the dynamism of cultivated land within the same farm (increased or decreased area, analysed over a period of three

9 The center-periphery model created by Johann Heinrich von Thünen (1826), currently used to analyse peri-urban agriculture, defines concentric circles around the city-market. The spatial distribution of its agricultural and forest productions can be explained according to the proximity of the urban centre and profitability of expected production: at the nearest point, the most profitable agricultures produce perishable products that are difficult to transport (fruits, milk, vegetables); at the farthest point, the less intensive farmers need a lot of space and generate products that can be stored easily (cereals, livestock).

10 All the variables, with a brief description of the defined categories or recorded values for the study area of Avignon, are elaborated in detail in 2016 in Ether Sanz Sanz's Ph.D. thesis, *Planification urbaine et agriculture. Méthodologie systémique de caractérisation de l'agriculture périurbaine à partir d'une recherche empirique en France et en Espagne*.

11 Correlation matrices and statistical learning method Random Forest (algorithm of decision trees, formally proposed in 2001 by Leo Breiman), combined with a VIF endogeneity analysis (Variance Inflation Factor). All the statistical analyses were carried out using the software R.

years), “professionalization” of farms with respect to cultivated areas according to the main technico-economic orientation, diversification of the technico-economic orientations of the farms (mono-oriented versus diversified farms), the importance of areas classified as agricultural in the local urban planning scheme (*plan local d’urbanisme*, *PLU*), the percentage of built-up areas, the form of the border between agricultural and urbanised areas and the form of the plot. On the vertical axis, the type of tenure provides the highest contribution.

Fig. 5/ Multiple correspondence analysis of the spatial units of peri-urban agriculture in the study area of Avignon

In addition, the MCA conducted on the USAPUs makes it possible to group them according to their sensitivity to urban influence, following the logic of highlight the forms of peri-urban agriculture that are most sensitive to public regulations in order to focus institutional action on them. It also allows us to define a dynamism gradient of the USAPUs and hence establish a priority intervention gradient for an eventual public action. Two groups can thus be defined:

• On one hand, the USAPUs “sensitive” to the constraints and opportunities related to the proximity of urban areas. These are spatial units of peri-urban agriculture composed of small highly diversified farms, which have a strong presence of non-professionals as well as a fragmented plots that are often imbricated with the urban fabric. We define “sensitivity” in terms of real estate (increase or decrease in farming areas in a farm or shifting of cultivated plots without variation in the total farming surface area), in terms of agricultural practices (production of old varieties or organic certification to respond to urban demand) and in terms of marketing techniques (a large range of channels, from on-farm sale to large retailers). The sensitive USAPUs are reactive to urban demand and have more resources to adapt to changes.

• On the other hand, the USAPUs that are “stable” with respect to urban influence and which follow the agricultural sector rationale. They are composed of professional farms with a specific technico-economic cultivation approach on regular plots in the agricultural zone without any direct contact with urbanised zones.

On the second axis, the marketing technique of the farming areas also explains a part of the variance between the USAPUs. Thus, we can define a third group corresponding to the “heritage” modes of peri-urban agriculture with a strong presence of owner-occupied farms (land is considered here as an asset). This is the case, for example, of lands located in AOC high-quality viticulture zones.

A tool for public action?

The USAPU approach serves as a tool for public action as it refers to actionable elements, as an alternative to the zoning[12] mechanisms and the current regulations under local urban planning schemes. Furthermore,to preserve the agricultural land use is necessary even though “protecting the land status is a necessary but insufficient condition for peri-urban agriculture” (Jarrige et al., 2009, p. 47). In this context, we could imagine, on one hand, rules for agricultural areas that are focused not only on the criteria for authorising an alternative use of existing agricultural buildings or conditions for allowing new constructions necessary for agricultural activity, but also on prescriptions: 1) pertaining to access and road network depending on the agricultural activity (for example, the minimum road width to be respected for the passage of agricultural vehicles), 2) pertaining to the landscape elements that need to be highlighted because of their heritage or production value (for example, irrigation canal network), 3) pertaining to the areas whose agricultural diversity should be preserved or developed to reinforce their connection with the city (for example, by advocating crop plots which are not very big and surrounded by hedgerows to avoid a regrouping and a shift to extensive opportunistic cropping)… On the other hand, criteria for agricultural land use and production forms could be defined like rules for industrial or business zones. Urban planning regulations cannot act immediately to materially organise agricultural activity and the processing of agricultural products, which come under agricultural sector-specific plans, but they can give guidelines on the implantation of necessary infrastructure. These criteria could be specifically set down as provisions applicable to each of the zones demarcated by the USAPUs. In this way, the “zone A” would be composed of several sectors (zone AA corresponding to the influence of USAPU-A, zone AB corresponding to that of USAPU-B, and so

12 In France, land-use planning practice divide land in a municipality into zones (e.g. residential, industrial) in which certain land uses are permitted or prohibited. The type of zone determines whether planning permission for a given development is granted. Zoning may also indicate the size and dimensions of land area as well as the form and scale of buildings. These guidelines are set in order to guide urban growth and development.

on), with distinct provisions depending on the type of agricultural activity, like urban zones U, which are coded according to their nature[13]. Agriculture would then be recorded in the urban development plans as an economic activity for which regulation provisions would ensure sustainability through prescriptions that are localised but general enough to leave a margin for negotiation with the stakeholders. This type of provisions is likely to correspond to the agricultural project of each municipality, in accordance with the inter-municipalityproject decided in the Territorial Coherence Programmes (*schéma de cohérence territoriale*), whose orientations are supposed to be a part of the Sustainable Development and Planning Project (*projet d'aménagement et de développement durable* – PADD) thus integrating agriculture as a productive economic activity in the development of the municipality. The PADD often raises issues related to the living environment and residential development, environmental quality, development of the service industry and economic hubs or mobility. But, except for rural municipalities eventually, agriculture is not addressed here. In addition, in the new context marked by concerns about food security and quality, local integration of agriculture as a food production sector becomes inevitable. Territorialisation of public action in the agricultural domain should thus allow one to go beyond sector-based logics, by bringing out new, smoother modalities of action which respond to local issues that are difficult to address at the national or the European scale. Finally, the USAPUs that are sensitive to the city influence, where farmers are capable of taking advantage of the opportunities offered by the urban market to sell their production in local distribution channels, open up avenues for developing a metropolitan agro-food system and the relocation of food supplies to cities.

Conclusion

Our objective was to propose a methodology for characterising peri-urban agriculture, which could steer public action towards places where there is more possibility of undertaking effective territorial projects. Given that the theoretical and methodological frameworks for documenting the issues related to forms and practices of peri-urban agriculture for urban planning purposes are incomplete, we tried to create a methodology enabling operational action. We developed an approach based on landscape as an expression of the agrarian system.We drew inspiration from the tools proposed by Jean-Pierre Deffontaines and Pascal Thinon in 2008 in order to characterise homogeneous landscape units according to their structure and dynamics by adapting them to the peri-urban context. In this perspective, we developed, in an inductive approach, a method for characterising peri-urban agriculture with the help of the analysis of a study area located around the urban area of Avignon. Formally, we first characterised peri-urban agriculture using a significant number of qualitative and quantitative elements derived from additional approaches: geographic, agronomic, economic or political. As a second step, we conducted statistical analyses to reduce the number of descriptive variables without sacrificing the explanatory capacity of our model.

With respect to the formal results, besides the methodological contribution, contrary to popular thinking, the distance from the reference city centre is not a determining criterion for characterising agriculture within the outer and inner borders of the peri-urban area. The various forms of peri-urban agriculture are not distributed in a distance gradient with respect to the city according to their technico-economic vocations, as in the case of a simplistic application of a "von Thünen" type approach. Other criteria, corresponding to the agro-ecological conditions and the history of the place in terms of urban planning and development of the agricultural sector, explain the variance between the USAPUs (see Triboulet, Langlet, 2002, for other examples).

Our methodology also enables a spatial representation of the peri-urban agricultural trends at the local scale. It proposes a classification of the USAPUs according to their sensitivity to urban influence, allowing one to focus public action on spaces and agricultural systems that could potentially be more reactive to institutional incentives offered by the urban authorities in the vicinity working for territory projects and agricultural land planning. From this point of view, the methodology is designed for use as a tool for taking decisions concerning spatial management of peri-urban agriculture.In this context, it contributes to:

• questioning the paradigm frequently used in urban planning of an ideal equilibrium plan in order to explore how to introduce new forms of territorial management that can be adapted to peri-urban

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13 In the local urban planning schemes, there are several types of urban zones: UA with housing as central, UB recent extension sector, UC urban zone with medium density, UD peripheral zone with the least density, UE reserved for economic activities.

areas.
• overcome the reductionism, city = urban and agriculture = rural to think of peri-urban as a complex system.
In this perspective, the methodological tools and more generally the scientific knowledge, can help local stakeholders to identify the landscape structure which could underpin common values, and use it in a dynamic project-based approach. Formally, the evolution of policy-level expectations pertaining to the inclusion of agriculture in urban management and the simultaneous regulatory evolution (LAAAF)[14], force the local elected representatives to take on agricultural management. In this sense, the USAPU approach is a semi-automated method that can be used in urban planning regulation structures. To construct our methodology for characterising peri-urban agriculture, we consulted the stakeholders. In future work, , it would be interesting to develop multi-stakeholder and multi-level research on territorial governance that would analyse the role of each of the parties in the decision-making process.

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